Numerical Simulation of Nonlinear Wave Interactions with a Wave Energy Converter

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ABSTRACT

This paper describes further developments of the AMAZON-SC 3D numerical wave tank (NWT) for nonlinear wave interactions with fixed and floating structures. The code is being used to study the behaviour of regular arrays of the Manchester Bobber Wave Energy Converter (WEC) in heave motion. AMAZON-SC 3D (see e.g. Hu et al. (2009)) uses a cell centred finite volume method of the Godunov-type for the space discretization of the Euler and Navier Stokes equations. The NWT has been validated by comparison with established theoretical and experimental data for a fixed cylinder case by comparison of vertical and horizontal forces. For the Bobber device, validating laboratory data is available for drop and rise tests. Results will be also presented for an isolated Bobber and an array of the device under regular wave conditions.

KEY WORDS: Nonlinear wave/body interactions, free surface capturing, wave energy devices, Cartesian cut cell method, Manchester Bobber.

INTRODUCTION

Any large-scale wave power farm will have a number of devices operating in relatively close proximity to each other. Consequently, the hydrodynamic interactions between neighbouring devices may modify significantly the performance of a single device relative to its performance when in isolation. The need for such calculations has been widely recognized by engineers in the wave energy community and attempts have been made to calculate the force due to waves, currents and wind and the resulting motion of the devices (e.g. Thomas and Evans (1981), Chid and Venugopal (2007) and Thomas al. (2008)). However, both the topology of the free surface and the geometry of the device can be complicated in practical cases. For example, the Manchester Bobber, designed by project partners at the University of Manchester in the UK, is a novel heaving point absorber device generating oscillatory shaft motion which is converted to unidirectional rotation through a freewheel/clutch which in turn drives an electricity generator. The Bobber represents a generic class of floating buoy device that involves unique combinations of the object motion and incident wave conditions. In order to assess the design and operational performance of the Bobber, proper specification of input conditions and a full set of flow variables is needed, e.g. pressure and velocity field, as well as integrated effects such as loadings and the device response which are usually the output parameters from physical experiments or CFD codes. However, the general problem is very complex, e.g. the range of wave characteristics varies from small ripples with long period oscillations to extremely high and steep waves appearing suddenly via interactions between comparatively smaller waves and nonlinear interactions between waves and the body as well as arrays of the device. Therefore, our present work requires significant continuing development for applications to practical and relevant deployments.

Our previous work Qian et al. (2006) on two fluid slamming problems, which involved a 2D rigid wedge-shaped body entering water and its subsequent total immersion, and 3D water entry of a rigid wedge, focused waves in an empty tank, and a floating Bobber in regular waves Hu et al. (2009) have all been used for code validation.

In this paper, we present extensions of our work with the AMAZON-SC flow solver that uses a Cartesian cut cell mesh in 3D and has been successfully applied to regular wave loading of fixed and floating bodies in a NWT. A numerical wave maker is installed at one end of the tank while a numerical beach based on a non-reflection boundary condition is adopted at the other end of the tank. Floating bodies in heave motion are placed at a convenient location in the tank where they will be set into motion by the waves generated by the numerical wave maker. Firstly, we consider two established bench-mark test cases involving a first order regular wave maker generating waves acting upon a fixed horizontal and fixed vertical cylinder. Secondly, we compare our results with experimental data for the free decay of the Bobber device during a drop test. Finally, cases involving regular waves acting on an isolated Bobber or an array of floating Bobber devices in a tank is considered. The calculations applied to the Bobber geometry illustrate the robustness of the boundary-conforming Cartesian cut cell approach.

In the current work, our AMAZON-SC 3D code has been extended to